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# Investigation and Simulation of Technical Power Losses on 33/11kv Distribution Feeders Based on Gauss-Seidel Iterative Approach

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**Abstract**

*Loss of technical performance is one of the main causes of energy shortages and inefficient operation of electrical machines in energy systems. In this study, an analysis of power losses for six selected 33/11 kV distribution feeders* was *presented. (Kakoba, Ntare, Karamurani, Ishaka MbararaNorth1 and Mbarara North 2) at Mbarara Central Substation Network of UMEME Electricity Distribution Company in Uganda. Data such as cable type, conductor resistance, conductor reactance, and route length were obtained from energy suppliers. From this data, the Gauss-Seidel method was used to determine the total active power and associated reactive power of the entire substation system. The findings showed that the substation is profitable due to the small calculated total power losses. Although it is possible to reduce the total loss to at least 9-12%. Losses were due to old* substations, *overloaded transformers, and copper losses core losses in lengthy feeder routes.*

*To improve the performance of power distribution networks, it was recommended to replace old conductors to reduce losses.*

**Nomenclature and units**

| | |
|---|---|
| NPV | Net present value |
| BCR | Benefit Cost Ratio |
| 1RR | Internal Ratio of Return |

## 1.0 Introduction

Consumers often suffer from the distribution system's issues when failures occur. A network of generation, transmission, and distribution systems makes up an electrical power system. This comprises electrical equipment that is linked to electrical types of machinery, such as transformers, generators, and AC induction motors. Plants, transformers, transmission lines, substations, distribution lines, and distribution transformers are the six essential parts of a power system. Transmission lines are used to carry electricity across vast distances. (Rao, 2008). Technical power loss refers to losses that are brought on by the physical makeup of the power systems' structure or equipment. Iron and copper losses in cables, transformers, generators, and switch operators are two examples. The two main pieces of electrical machinery utilized in electrical power systems are generators and transformers. Current influx via the cables' resistance causes losses in generators, transformers, and distribution cables. Power may be reduced when a comparable current is running through a conductor by replacing it with one of the bigger diameters and switching to a material that provides lower resistance. (Mahmood et al., 2014).

All load flow studies and calculations were done manually before 1929. In 1929, a network calculator (Westinghouse) or a network analyzer was used to calculate load flow (General Electric).

(Anumaka, 2012) To illustrate the first digital approach to solving the load flow issue, the first paper was created in 1984. However, with the Ward and Hale approach, research into effective digital methods for load flow estimation started in 1956. The Gauss-Seidel technique's Y-Matrix is the foundation of the majority of early repetition algorithms. Ac/Dc load flow methods and other typical load flow techniques fall into these two groups. (Lal, 2014)

When studying an energy system utilized for planning as well as for operation, power flow analysis is particularly helpful. He wanted a repeated high-speed performance flow solution for improving specific applications, particularly energy and distribution automation. These applications are amazing because they resolve power flow analysis so well. The common transmission system's generic meshed topology is where techniques like Newton-Raphson and direct Gauss-Seidel (bus impedance matrix) are built. Additionally, the high R/X ratio of distribution systems renders them unsuitable for using quick decoupled Newton techniques, which connect in most situations, in place of a more conventional force of flux methods. Finally, the bus voltage affects PQ loads in a distribution system. However, the majority of conventional power flow techniques in both transmission and distribution systems treat power needs as defined constants with constant values. This is particularly true for a distribution system since the bus voltage is not adjusted and the constant load model is quite dubious. Therefore, the load flow approach more usefully considers this issue to produce better and more accurate findings. On the other hand, successful efforts have been made to develop algorithms for a power flow analysis of transmission systems. Therefore, it should be noted that the necessity for distributors to conduct more thorough research and expand system automation drove the creation of an algorithm for a distribution system that takes each unique attribute into account. It is commonly recognized that all networks must be examined when using the efficient power flow technique, one of the most helpful and demanding pieces of software in the power business. Today's technology places a lot of importance on distribution network analysis. The key tenet of the load flow approach was the node-level conversational idea. To address the radial distribution networks, a method based on Kirchhoff's rules of voltage/current has also been used. However, the numerical method necessitates expanding the radial configuration network and the number of breakpoints needed for conversion. (Talukdar, 2019) To tackle the load flow issue in the distribution system, Wu and Baran employed an iterative technique with three basic expressions that represent the PQ power and voltage magnitude. These equations were useful since they could be applied to both actual equipment and acceptable forms of use. If convergence is not found, a new similar network was built using fresh variables, and the process was repeated until convergence was attained.

Musinguzi (2019) delivered his paper to the engineering school 2019 about the technical loss reduction of the MV distribution network via load switching. The research modeled the load flow analysis using via and dig silence to show how technical losses on MV distribution network load switching may be reduced. (Daniel, 2019).

The proposed algorithm was validated using Gauss-Seidel and MATLAB software compared to the existing related work most of them which Dig silent software. This research work identifies the percentage total of l real and reactive power losses that influence electrical power performance in 11/33kV distribution feeders of (Kakoba, Ntare, Karamurani, Ishaka MbararaNorth1and Mbarara2) at Mbarara central substation in Uganda Mbarara district. The condition of all relevant equipment for power distribution in the aforementioned feeders was assessed as load flow analysis. The determination of total real and reactive power for the Mbarara central substation the using Gauss seidel method for load flow analysis was considered.

### 1.1 Review of Studies on Methods of Load Flow Simulation in Distribution Systems

Load flow means the numerical analysis of electrical power flow in the electrical system. The principle of power flows is to determine active and reactive power, voltage, current, and flow in a system that is under any load condition. Load flow studies are among the most interesting and important though difficult analyses in power network studies. Power flow studies ensure the ability of the network to sufficiently load supply and bus remain within the desired range of voltage and current. This helps in getting power factor and voltage current and power flowing across the entire busses. These buses are categorized into three different types: slack/swing buses, PV buses, PQ buses, and voltage-controlled buses. At each bus, we are interested in only four quantities: reactive and active power, voltage magnitude, and phase angle. Since their solution is based on iterative techniques only due to their nonlinearity of algebraic expressions.

#### 1.1.1 Importance of power flow studies

1. Load flow studies are so important, especially during planning, arranging, and designing a future expansion of the power system.
2. Load flow studies are needed for deciding the economic system's stability.
3. Load flow studies give the phase angles, nodal voltages at each of the buses, and power flow via interconnected power channels.
4. Load flow studies give the starting condition of the system fleeting behavior of the system is to be looked at.

## 1.2 Methods of Load flow used in Power Systems

The following methods are used mostly for load flow analysis.

- Gauss-Seidel load (GS)flow method
- Newton–Raphson method
- Fast Decoupled Newton Raphson
- Decoupled Newton Raphson
- Backward /Forward Sweep Method
- BIBC/BCBV Method

### 1.2.1 Gauss-Seidel load (GS) flow method

This method is categorized into two: Admittance Gauss-Seidel method (YGS) matrix and Impedance Gauss seidel method (ZGS) The method is specifically for no-zero diagonal elements matrices. This method has a much slower convergence speed than other methods, but requires minimal computer memory and requires fewer interactions on smaller networks. Therefore it doesn't necessarily solve the matrix.(Sedghi & Golkar, 2016).

### 1.2.2 Newton–Raphson

This is a milestone in the load flow solution method. Several approaches are based on this technique, it is based on the NR algorithm for solving simultaneous quadratic expressions in the power grid, and the convergence speed is very fast. The recursive power flow equations for reactive and real power (Pi, Qi) are used as the core equation. When using the voltage Phasor rectangle, the power flow method is called the rectangular coordinate method and when using the voltage Phasor shape, the load flow method is called the rectangular polar coordinates method (Talukdar, 2019)

### 1.2.3 Fast Decoupled Newton Raphson

From Newton-Raphson, it is observed that the difference in real power is highly affected only by changes in load angle and voltage magnitude differences. Increase similarly changes in reactive power (Pi, Qi) is very much influenced by the changes in voltage magnitudes and no changes take place due to the load angle changes. (Alsac & Stott, 1974) This forms the basis for rapid load flow conditions and is called the Approximate Newton method. The iteration method corresponds to the Newton-Raphson method, and the memory requirement is significantly reduced, the resolution must be decoupled and converged and the conductivity of the serial branch must be smaller than the series branch susceptance.

### 1.2.4 Backward /Forward Sweep Method

This is also another method of load flow analysis and has two steps: Forward and Backward Sweep. Kirchhoff's power Law and Kirchhoff's tension are used during the reverse current to enumerate the bus voltage of the last node of each line transformer branch. It then uses linear proportionality to determine the ratio of the real and imaginary parts of the voltage given by the calculated voltage of the substation bus. The work of the Forward Sweep step is mainly to calculate the voltage drop of the feeder (Liu et al., n.d.). In 1967 Berg et al. Presented the Backward method where the sending end impedance was updated due to the backward procedure, keeping the load a constant impedance is the major importance of this method.
In 1989, Baran et presented the forward sweep procedure where the target is on the voltage at the sending end of the network. This method is very complex and expensive since it requires oriented ladder system concepts. Recently Nandaetal also presented a fresh backward algorithm due to the much load on the feeder. This normally leads to more iteration.

#### 1.2.5 Bus Injection to Bus Current /Branch current Bus Voltage Method

This load flow analysis method consists of the two matrices that created the matrix, a bus injection to the bus current and branch current to bus voltage which uses simple matrix multiplication to acquire load flow solutions. This solution connects very quickly, so resulting in a very short execution time.
Although the mentioned methods described above correspond to it. The main limitation of the NR method is the large storage and large solution time. It depends on repetitive Formation and a three-sized Jacobean matrix. When a specific approximation is performed in the Jacobean elements, an approximate network that has been explained as a Fast Decoupled Load Flow method has appeared. Calculation efficiency and reliability of rapid separation type load flow are observed to be used as a major mathematical tool for calculating a

thousand flows of near networks of the energy industry, higher than the NR method. The negative side of the rapidly separated load flow was observed to have a faulty solution for high (R/X) ratio networks (Talukdar, 2019). The above-mentioned 'methods normally fail to analyze the distribution network due to the very sparse network admittance matrix Ybus, R/X ratio, and higher feeder loading as a result. Also, the Back/Forward sweep does not need a Jacobian matrix, unlike Newton Raphson's method. The back/Forward sweep method is much used in practice though not useful for a modern active distribution system.

In year 2016 (Sedghi & Golkar, 2016), solved the problem of simulations in new distribution systems through simulation mesh and DG modeling was the most main challenge for new distribution network load flow. Since the network includes so many loops then DG units must be high. During the Analysis and compassion of load methods for the new Distribution system, the following most important load flow methods of the load flow for the new Distribution system were categorized into two six groups.

1. Artificial Intelligence based method
2. Optimization based
3. Artificial Neural Networks based
4. Superposition base method
5. Compensated Back/Forward based
6. Newton Raphson based
7. Current Injection based
8. Improved Hybrid
9. Branch Impedance based
10. PSO- based Algorithms

Furthermore, during Network Reconfiguration for load balancing in radial Distribution system using different methods were used for power flow analysis that is: Gauss seidel, Newton Raphson, and Fast Decoupled methods. This found that Newton Raphson was the best method to use to solve this problem (Sedghi & Golkar, 2016) Therefore it was taken to be best among others that were used since it's the most reliable, it converges faster and it takes few numbers of iteration compared to others. Though this method takes longer in computing time.

Additionally, the Gauss-Seidel approach is advantageous over the aforementioned methods for power flow studies because the software task computation is reduced. More to that, it is efficient for systems with fewer buses and required less memory.MATLAB simulation software was used in simulating the 33/11kV distribution feeders connected to Mbarara central substation.

## 2.0 Materials and Method

This research work of the investigation and simulation of Technical Power Losses connected to the two 33kv incoming lines and four 11kv outgoing lines aforementioned in the Mbarara central substation UMEME Uganda distribution company. The power rating of distribution transformers and line diagram was collected using GIS, Mastech digital power clamp meter model Ms2203, Robin Earth Tester model 4102, and measurement tape. Gauss Seidel's approach was used for load flow analysis using MATLAB simulation software.

## 3.0 Results

Based on the aforementioned findings, a power flow calculation was created using the Gauss-Seidel load flow analysis in MATLAB at 33 iterations and 0.234 seconds of computing time, with total real power losses of 14.16% and total reactive power losses of 42.47%. 33 iterations were necessary to obtain convergence. From the following bellow,

### 3.1 Calculating the P.u values of Mbarara central substation feeder parameters:

Based on the data give. The schedule of active and reactive powers, acceleration factor (α =1.0), assume,

The line admittances $Y = \frac{1}{Z}$ … … … … … … … … … … … … … (1)

In this examination of power networks, it is customary to represent numbers as a percentage of reference quantities, such as rated or full-load values, rather than using their actual values. These fractions are known as per unit fractions (abbreviated as p.u), and the p.u. value of any quantity is defined as follows.

$$Z_{P.U} = \frac{Z_A}{Z_B} = \frac{z_{actual}}{z_{base}} \quad (2)$$

Where $Z_{P.U}$, is the per unit impedance, $Z_A$, s the impedance actual value and $Z_B$ is the impedance base value

$$Z_B = \frac{(KV_{LL})^2}{MVA_{3\phi}} \quad (3)$$

Where,

$Z_B$, is base impedance, $KV_{LL}$, is the base voltage (kilo volts line -to-line) and $MVA_{3\phi}$ Is the base power

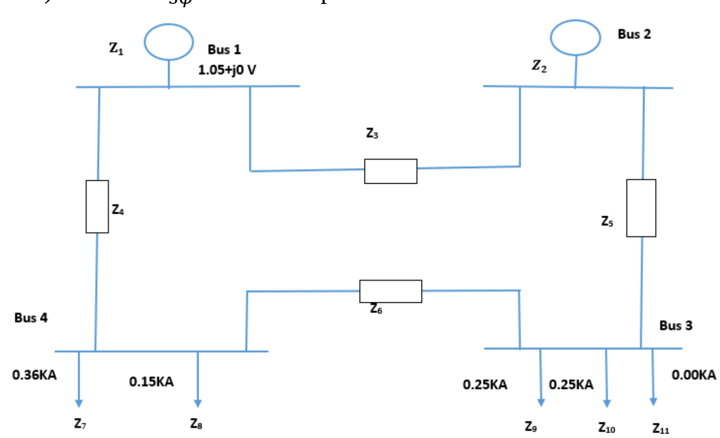


**Figure 1:** System Line Diagram.

From the line diagram above for Mbarara central substation the following Y bus matrix was obtained.

Y bus =

| | | | |
|---|---|---|---|
| 1.4379e^3 - j8.1032e^2 | -7.0064e^2+j3.8217e^2 | 0 | -7.0064e^2+j3.8217e^2 |
| -7.0064e^2+j3.8217e^2 | 1.4400e^3 - j8.1266e^2 | -7.0064e^2+j3.8217e^2 | 0 |
| 0 | -7.0064e^2+j3.8217e^2 | 1.4145e^3-j7.7312e^2 | -7.0064e^2+j3.8217e^2 |
| -7.0064e^2+j3.8217e^2 | 0 | -7.0064e^2+j3.8217e^2 | 1.4409e^3-j8.0085e^2 |

**3.2 Solving for voltages Set Initial voltage estimates:**

Assume,

Slack bus: $1.05\angle 0^0$, others buses $1\angle 0^0$

$V_2^{(0)}, V_3^{(0)}, V_4^{(0)}$ First iteration:

$$V_2^{(1)} = 1/Y_{22}\left[\frac{P_2{,}sch - jQ_2{,}sch}{V_2^{(0)*}} - \; Y_{21}\, V_1^{(0)} - Y_{23}\, V_3^{(0)}\right] \text{……… (4)}$$

If buses 3 and 4 are load buses, this means that $P_{3,sch}$, $Q_{3,sch}$, $P_{4,sch}$, $Q_{4,sch}$ are known, hence:

$$V_3^{(1)} = 1/Y_{33}\left[\frac{P_3{,}sch - jQ_3{,}sch}{V_3^{(0)*}} - \; Y_{32}\, V_2^{(1)} - Y_{34}\, V_4^{(0)}\right] \text{……… (5)}$$

$$V_4^{(1)} = 1/Y_{44}\left[\frac{P_4{,}sch - jQ_4{,}sch}{V_4^{(0)*}} - (\; Y_{41}\, V_1^{(1)} \; + Y_{43}\, V_3^{(1)})\right] \text{…. (6)}$$

The process is repeated again and again until the correction in voltage reaches a predetermined precession index. In general, with N-bus system:

$$V_i^{(k)} = 1/Y_{ii}\left[\frac{P_i{,}sch - jQ_i{,}sch}{V_i^{(k-1)*}} - \sum_{j=1}^{i-1} Y_{ij} V_j^{(k)} - \sum_{j=I+1}^{N} Y_{ij} V_j^{(k-1)}\right] \text{…………………………………………(7)}$$

Where (K) denotes the number of the current iteration & (k-1) ″ ″ preceding (All & Majors, 2010)

Now,

$$V_2^{(1)} = 1/Y_{22}\left[\frac{P_2{,}sch - jQ_2{,}sch}{V_2^{(0)*}} - (\; Y_{21}\, V_1^{(0)} \; + Y_{23}\, V_3^{(0)})\right] \text{…… (8)}$$

$$V_2^{(1)} = 1/(\; 1.4400e\text{^}3 \; - \; j8.1266e\text{^}2)\left[\frac{1-j1}{1} - (\; (-7.0064e\text{^}2 + j3.8217e\text{^}2)\;(1.05) \; - 1.0(-7.0064 + i * 3.8217)\right] \text{………(9)}$$

$\boldsymbol{V_2^{(1)}}$ **= 0.0250+j0.0001**

$$V_3^{(1)} = 1/Y_{33}\left[\frac{P_3{,}sch - jQ_3{,}sch}{V_3^{(0)*}} - (\; Y_{32}\, V_2^{(1)} \; + Y_{34}\, V_4^{(0)})\right] \text{…..(10)}$$

$$V_3^{(1)} = 1/Y_{(1.4145e\text{^}3 - j7.7312e\text{^}2)}\left[\frac{1.75 - j1.75}{1 - j0} - (\,-7.0064e\text{^}2 + j3.8217e\text{^}2)(0.0250 + \text{j}0.0001) - (-7.0064e\text{^}2 + j3.8217e\text{^}2(1.0))\right] \text{…………………………………………(11)}$$

$\boldsymbol{V_3^{(1)}}$ **=-0.4812-j0.0008**

$$V_4^{(1)} = \frac{1}{Y_{44}\left[\frac{P_4{,}sch - jQ_4{,}sch}{V_4^{(0)*}} - \left(\; Y_{41}\, V_1^{(1)} + Y_{43}\, V_3^{(1)}\right)\right]} \text{… … … … … … (12)}$$

$$V_4^{(1)} = 1/(1.4409\text{e}\text{^}3 - \text{j}8.0085\text{e}\text{^}\mathbf{2})\left[\frac{3.5 - j3.5}{1 - j0} - (\; -7.0064\text{e}^2 + \text{j}3.8217\text{e}^2)(\mathbf{1.05}) - (-7.0064\text{e}\text{^}2 + \; \text{j}3.8217\text{e}\text{^}2)(\mathbf{-0.4812 - j0.0008})\right]. \text{…………………………………… (13)}$$

$\boldsymbol{V_4^{(1)}}$**= 0.7414+j0.0062**

**3.3 MATLAB Gauss-Seidel Power Flow simulation results**

Number of iterations: 33

Solution time: 0.234 sec.

Total real power losses: 0.141554.

Total reactive power losses: 0.424661

**Table1:** Real and Reactive Power Losses at Generation and Load

| | | | Generation | | Load | |
|---|---|---|---|---|---|---|
| Bus | Volts | Angle | Real | Reactive | Real | Reactive |
| 1.0000 | 1.0500 | 0 | -2.1584 | -2.1853 | 0.1500 | 0.0700 |
| 2.0000 | 1.1452 | 2.4074 | 0 | 0 | 0.1700 | 0.0900 |
| 3.0000 | 1.2017 | 3.7320 | 0 | 0 | 0.1700 | 0.0900 |
| 4.0000 | 1.1758 | 3.1143 | 0.0400 | 0.1100 | 0.1700 | 0.1000 |

**Line Flows**

| Line | From Bus | To Bus | Real | Reactive |
|---|---|---|---|---|
| 1.0000 | 1.0000 | 2.0000 | -1.2522 | -1.2312 |
| 2.0000 | 1.0000 | 3.0000 | -0.5037 | -0.4845 |
| 3.0000 | 1.0000 | 3.0000 | -0.5037 | -0.4845 |
| 4.0000 | 1.0000 | 4.0000 | -0.5525 | -0.5397 |
| 5.0000 | 2.0000 | 4.0000 | -0.2120 | -0.2207 |
| 6.0000 | 3.0000 | 4.0000 | 0.7682 | 0.7813 |
| | | | | |
| 1.0000 | 2.0000 | 1.0000 | 1.3082 | 1.3990 |
| 2.0000 | 3.0000 | 1.0000 | 0.5391 | 0.5908 |
| 3.0000 | 4.0000 | 1.0000 | 0.5850 | 0.6371 |
| 4.0000 | 3.0000 | 2.0000 | 0.2727 | 0.2880 |
| 5.0000 | 4.0000 | 2.0000 | 0.2148 | 0.2292 |
| 6.0000 | 4.0000 | 3.0000 | -0.7598 | -0.7563 |

Based on the aforementioned findings, a power flow calculation was created using the Gauss-Seidel load flow analysis in MATLAB at 33 iterations and 0.234 seconds of computing time, with total real power losses of 14.16% and total reactive power losses of 42.47%. 33 iterations were necessary to obtain convergence.

### 3.4 Cost Benefit Analysis (CBA)

This entails weighing a project's benefit vs cost to see if it will be profitable to carry it forward. Three standard modules are used in the CBA computation:

a. Net present value (NPV)

b. Benefit Cost Ratio (BCR)

c. Internal Rate Of Return (IRR)

$$NPV = \sum Present\ Value\ of\ future\ benefits - \sum Present\ Value\ of\ future\ cost \quad \ldots\ldots (13)$$

$$BCR = \frac{\sum Present\ Value\ of\ future\ benefits}{\sum Present\ Value\ of\ future\ cost} \quad \ldots\ldots (14)$$

(Improvement & Program, 2012)

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1+IRR)^t} - C_0 \ldots\ldots (15)$$

Where,

$C_t = Net\ cash\ inflow\ during\ the\ period\ t$

$C_0 = Total\ intial\ ivestmennt\ costs$

$t = The\ number\ of\ time\ periods$

Understanding the costs and advantages of implementing solutions to decrease transmission and/or distribution system losses is necessary for making the right choice. Costs and benefits may be compared to the system's baseline predictions. Costs associated with strategy include those associated with formulating and implementing a plan, running and maintaining capital equipment,

The advantages of loss reduction techniques include greater capacity for power production, transmission, and distribution, as well as direct cost savings by lowering the quantity of electricity lost (e.g., less power is produced to fulfill the same demand). includes savings over the long run or indirect savings from lowering needs. The number of losses prevented and the cost of power production averted will determine the direct cost reduction. Because the loss reduction value is correlated with the cost of production at the moment of reduction, calculating this cost may be challenging.

**Table 2:** Economic internal Rate of Return (EIRR)

| Economic Analysis (NPV, BCR, IRR calculation) | | | | | | | | | | | (in USD) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SL. No. | Fiscal Year Starting | Economic Capital Cost | Operating Cost | Total Cost | Total Benefit | Discounted Value of Total Cost at | Discounted Value of Total Benefit at | Discounted Value of Total Cost at | Discounted Value of Total Benefit at | Discounted Value of Total Cost at | Discounted Value of Total Benefit at |
| | | | | | | 12.00% | 12.00% | 15.00% | 15.00% | 18.00% | 18.00% |
| 1 | 2013 | 750,000 | - | 750,000 | - | 669,643 | - | 652,174 | - | 635,593 | - |
| 2 | 2014 | 30,000,000 | 15,000 | 30,015,000 | 12,340,630 | 23,927,774 | 9,837,875 | 22,695,652 | 9,331,289 | 21,556,306 | 8,862,849 |
| 3 | 2015 | 20,000,000 | 615,000 | 20,615,000 | 29,695,151 | 14,673,350 | 21,136,422 | 13,554,697 | 19,525,044 | 12,546,925 | 18,073,386 |
| 4 | 2016 | 5,300,000 | 630,000 | 5,930,000 | 31,677,969 | 3,768,622 | 20,131,922 | 3,390,497 | 18,111,981 | 3,058,628 | 16,339,144 |
| 5 | 2017 | | 630,000 | 630,000 | 32,691,416 | 357,479 | 18,549,988 | 313,221 | 16,253,412 | 275,379 | 14,289,719 |
| 6 | 2018 | | 630,000 | 630,000 | 29,717,753 | 319,178 | 15,055,938 | 272,366 | 12,847,805 | 233,372 | 11,008,393 |
| 7 | 2019 | | 630,000 | 630,000 | 28,656,851 | 284,980 | 12,962,904 | 236,840 | 10,773,172 | 197,773 | 8,996,103 |
| 8 | 2020 | | 630,000 | 630,000 | 25,278,138 | 254,446 | 10,209,416 | 205,948 | 8,263,468 | 167,604 | 6,724,949 |
| 9 | 2021 | | 630,000 | 630,000 | 25,385,182 | 227,184 | 9,154,151 | 179,085 | 7,216,053 | 142,037 | 5,723,243 |
| 10 | 2022 | | | - | - | - | - | - | - | - | - |
| 11 | Salvage Value | | - | - | 0 | - | 0 | - | 0 | - | 0 |
| | **Total** | | | | | **44,482,656** | **117,038,616** | **41,500,482** | **102,322,224** | **38,813,617** | **90,017,786** |
| | | | | **Discount Rate** | | 12.00% | | 15.00% | | 18.00% | |
| | | | | **NPV** | | 72,555,959 | | 60,821,742 | | 51,204,169 | |
| | | | | **BCR** | | 2.631 | | 2.466 | | 2.319 | |
| | | | | **IRR** | | 21.32% | | | | | |

The discount rate that balances the overall discounted benefits with the total discounted expenses is known as the Economic Internal Rate of Return (EIRR). It can be described mathematically in the way that follows:

$$\sum_{k=1}^{n} \frac{B_k}{(1+i)^k} = \sum_{k=1}^{n} \frac{C_k}{(1+i)^k} \ldots\ldots (16)$$

Where: Bk: Benefit for year k

Ck: cost for year k (Improvement & Program, 2012)

**Table 3:** Financial internal rate of return

| Financial Analysis (NPV, BCR, IRR calculation) | | | | | | | | | | | (in USD) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sl. No | Fiscal Year | Financial Capital Cost | Operating Cost | Total Cost | Benefit | Discounted Value of Total Cost at | Discounted Value of Total Benefit at | Discounted Value of Total Cost at | Discounted Value of Total Benefit at | Discounted Value of Total Cost at | Discounted Value of Total Benefit at |
| | | | | | | 12.00% | 12.00% | 13.00% | 13.00% | 14.00% | 14.00% |
| 1 | 2013 | 750,000 | - | 750,000 | | 669,643 | - | 663,717 | - | 657,895 | - |
| 2 | 2014 | 30,000,000 | 15,000 | 30,015,000 | 6,354,765 | 23,927,774 | 5,065,980 | 23,506,148 | 4,976,713 | 23,095,568 | 4,889,785 |
| 3 | 2015 | 20,000,000 | 615,000 | 20,615,000 | 15,015,174 | 14,673,350 | 10,687,504 | 14,287,229 | 10,406,269 | 13,914,538 | 10,134,815 |
| 4 | 2016 | 5,300,000 | 630,000 | 5,930,000 | 16,022,554 | 3,768,622 | 10,182,623 | 3,636,980 | 9,826,932 | 3,511,036 | 9,486,638 |
| 5 | 2017 | | 630,000 | 630,000 | 16,514,197 | 357,479 | 9,370,599 | 341,939 | 8,963,245 | 327,202 | 8,576,956 |
| 6 | 2018 | | 630,000 | 630,000 | 14,892,323 | 319,178 | 7,544,914 | 302,601 | 7,153,059 | 287,020 | 6,784,742 |
| 7 | 2019 | | 630,000 | 630,000 | 14,280,233 | 284,980 | 6,459,652 | 267,788 | 6,069,965 | 251,772 | 5,706,914 |
| 8 | 2020 | | 630,000 | 630,000 | 12,438,040 | 254,446 | 5,023,516 | 236,981 | 4,678,691 | 220,852 | 4,360,268 |
| 9 | 2021 | | 630,000 | 630,000 | 12,438,040 | 227,184 | 4,485,282 | 209,717 | 4,140,435 | 193,730 | 3,824,796 |
| 10 | Salvage Value | | - | - | - | - | 0 | - | 0 | - | 0 |
| | **Total** | | | | | **44,482,656** | **58,820,070** | **43,453,100** | **56,215,309** | **42,459,612** | **53,764,914** |
| | | | | **Discount Rate** | | 12.00% | | 13.00% | | 14.00% | |
| | | | | **NPV** | | 14,337,413 | | 12,762,209 | | 11,305,302 | |
| | | | | **BCR** | | 1.322 | | 1.294 | | 1.266 | |
| | | | | **IRR** | | 21,76% | | | | | |

The most typical use of this metric is in financial analysis. Project internal rate of return and return on equity are both included in FIRR, depending on the funding source.

According to the tables above, the project is lucrative and has a good chance of being expanded upon and implemented in the future since the NPV estimated is larger than zero (Reduction, 2013).

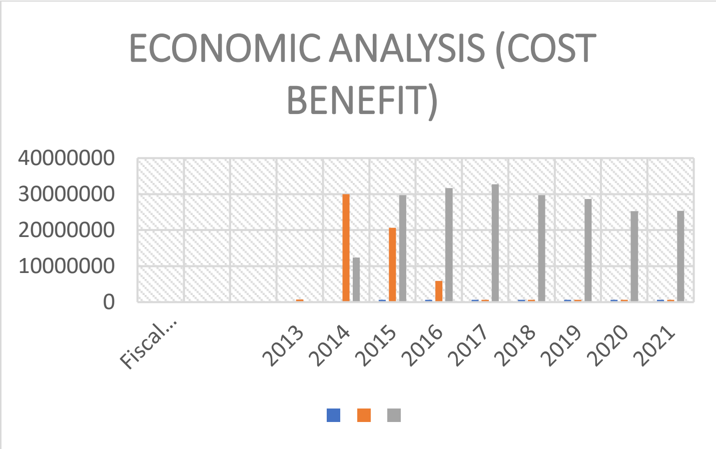


**Figure 2:** Economic Analysis (Cost Benefit).

## 4.0 Discussion

In this study, losses on the feeders of the Mbarara central substation were simulated using a Gauss-Seidel power flow algorithm. A simple way to increase electrical efficiency in power distribution systems is to reduce line losses. Investments in better network components and the greatest levels of on-demand and demand-side load control have made it possible to achieve large efficiency benefits due to advancements in technology and knowledge. Avoid overloading electrical equipment at feeders at the Mbarara substation for the sake of safety and dependability. The Mbarara Central Substation power system needs to improve voltage stability, reduce technical losses, and make the most use of off-site electricity.

## 5.0 Conclusion

This research work investigates the technical losses in distribution feeders of the Mbarara Central substation. The simulation of losses across the buses and lines was computed using the Gauss seidel method on MATLAB software. In addition, the financial and economic cost benefits (NPV and IRR) of the substation were calculated. Based on the computed results of both the losses (real power loss and reactive power loss) and the cost befits, the power plant is deemed economical and highly profitable to both stakeholders, the government, and the community at large. Finally, mitigation measures to minimize the power losses were discussed in detail.

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## 7.0 Declaration of conflict of interest

The author declares no conflict of interest.

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